Using mammalian Skulls to Enhance Undergraduate Research on Skeletal Trauma in a Forensic Anthropology Course.

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Abstract: Hands-on activities are favored learning techniques in STEM fields. In forensic anthropology courses, some of the content is hands-on but frequently is passive. Students typically observe bones, trauma, and post mortem intervals but rarely have the opportunity for active techniques such as reconstruction. It is unwarranted to demolish human remains to teach skeletal reconstruction, and digital reconstruction is challenging due to 3D technology's steep learning curve, but this information is important for students wishing to pursue careers in skeletal identification. The purpose of this pilot project was to incorporate other mammalian skeletons in place of humans and create an in-class research project relevant to forensic anthropology. Three deer skulls were acquired from local hunters. The specimens were thawed, skinned, flensed, and skeletonized using dermestid beetles. Skulls were inflicted with random trauma and presented to the students. In groups of two, students reconstructed their skull and identified all skeletal trauma, then presented a research poster to the class. Students answered survey questions at the end of the semester to assess their learning experience with 100% feeling they were more competent in the field of forensic anthropology. Pre and post exams showed that 50% of the students demonstrated a 7% grade increase.
Keywords: Forensic anthropology, dermestid beetles, laboratory activity, forensic science, hands-on learning

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Introduction

Forensic anthropology is a science of precision and responsibility (1). Forensic anthropology courses focus on concepts such as advanced osteology and skeletal trauma. Students in these courses learn techniques such as osteology, osteometric analysis, identifying characteristics such as age, sex, ancestry, and height, anthroposcopic analysis, 3D scanning and other conservation techniques (2-4). In the classroom or laboratory environment, institutions provide plastic casts, antique teaching skeletons, and photographs for students' learning. A limitation of this approach is that the majority of these resources offer passive hands-on learning. Students observe and touch, but do not alter. Due to a combination of insufficient school funding and a passive learning approach, students may end up lacking the necessary undergraduate research experience or hands-on learning experiences essential in courses such as forensic anthropology or osteology.

According to Wei and Wooden (5), the best approach to engage students is to introduce them to real work that scientists do, but to do so in the classroom. This concept informed the approach described in this paper. Students in the present study observed their instructor in her area of expertise using dermestid beetles to prepare skeletal materials. The purpose of this project was to give forensic anthropology students a half-semester skeletal reconstruction project to advance their abilities to determine skeletal trauma and reconstruct skeletons for future conservation and analysis while equipping instructors with the knowledge to reproduce this experience.

Materials and Methods:

Our small forensic anthropology course (n = 6) was split into groups of two, and each group was given a trauma-inflicted skull to reconstruct. To complete this project the students were required to apply everything they learned throughout the semester in order to analyze and reconstruct the skull. As it would be inappropriate to damage authentic human materials, we relied on donated deer heads that were exposed to dermestid beetles. Each skull underwent trauma with a different tool. Students analyzed the bones and trauma inflicted on each bone; then they reconstructed the skull. The students presented their final project in the form of a scientific research poster. Students also participated in a small survey to assess learning and their overall evaluation of the project.

Dermestid beetle care and set-up:

This project began with the purchase of a dermestid beetles #1 Starter Kit from Skulltaxidermy.com. Beetles were placed in a twenty-gallon aquarium with a thin-layer of cotton batting, a cup of dry dog food, and a mesh lid. Room temperature was monitored and maintained at approximately 21˚C. In hotter temperatures, beetles will fly and lower temperatures cause beetles to hibernate. Thus temperature maintenance is of paramount importance. The lights were left off and only turned on as needed, and beetles were left undisturbed except when watered weekly.

Figure 1 Flensed material in beetle tank with paper towels removed.

For this forensic anthropology project I used three white-tailed deer (*Odocoileus virginianus)* skulls. The deer skulls were donated to the forensic science program by local hunters during deer season. The heads remained frozen until needed, at which point the deer heads were thawed in a refrigerator on a dissecting tray. Once thawed, to prepare the skulls I 1) carefully skinned and flensed to limit scrape marks on the bones, 2) removed eyes and tongues, 3) removed brains using high-pressure water, 4) patted specimens dry with paper towels, 5) placed specimens in the beetle tank, and 6) covered the skulls with a dry paper towel (Figure 1). Colony size dependent, it takes between two and three weeks for the beetles to completely clean one skull.

Once a skull was completely defleshed, it was removed from the beetle tank and immediately placed into a bucket of warm soapy water with a cap-full of ammonia. This process kills any residual beetles and removes some oils (degreases) from the bone. (It is important to kill the beetles as they will destroy anything if freed.) Bones were left to soak for one week then removed and set out to air dry. Leaving the skulls in the water for too long will break down the cartilage, and the bones will naturally disarticulate along suture lines.

Figure 2 Three deer skulls after being cleaned and degreased. They were placed in their own dissecting tray with a thin foam lining. This lining was used during the trauma-inflicting process to help cushion and protect small bone fragments.

Once the deer skulls were skeletonized, they were placed into their own dissection tray (Figure 2). I randomly selected three tools to inflict trauma on each deer skull. Prior to starting this project we covered blunt force trauma, sharp force trauma, and projectile trauma in lecture. The tools I used to inflict trauma in this project were a handsaw, a ball-peen hammer, and a crowbar. I had intended to inflict a bullet wound on one skull but was concerned I would lose pieces because I would have to take the skull home and inflict the trauma outside. (It is likely quite difficult to discharge a firearm on many college campuses.) I inflicted a random number of blows on each skull with the appropriate tool until sufficient bony damage was present (Figure 3). Skeletal trauma can be more or less advanced depending on the area of focus and course level. To account for small bone fragments, the skulls were damaged in their respective dissecting trays (Figure 3).

Figure 3 The deer skull inflicted with blunt force trauma caused by the ball-peen hammer. All small skeletal fragments are present in the dissecting tray. As you can see, there was a random number of blows in different areas of the skull.

Student groups and skull assignments were randomly assigned using Rook cards. Students matched their card to their partner's card and card located with the skull. Once student groups obtained their skull, each group conducted a standard osteological analysis. This consisted of age (fawn, young, adult), sex of the deer, and a skeletal inventory of all damaged bones. Students differentiated between skeletal weathering, scrape marks from flensing, and trauma I inflicted on the skulls. Prior to beginning their reconstruction, students learned about museum preparation techniques and commonly used techniques to repair bones with wire and glue. For this project students used Elmer's school glue because it dries clear and is commonly used to repair skeletons. Due to the course level, I informed the students to focus on the external skeletal morphology and not internal morphology. Once the skulls were articulated, they determined the number of blows, type of trauma (blunt, sharp, projectile), and potential type of tool used (Figure 4).

To complete this project students were given four three-hour laboratory classes and expected to come into lab outside of class as needed. Students were given a confidential survey to complete on Blackboard about their experience. At the end of the semester each group was required to present a research poster to the class. This project was 45 CFR 46.101(b)(1) exempt.

Figure 4 A deer skull rearticulated after being subjected to sharp force trauma. Red arrows indicate blade marks.

Results

This specific forensic anthropology course was a 300-level, undergraduate, forensic science, majors-only, elective course. Students enrolled in this course have completed introductory biology, genetics, and forensic biology. Half of the class had previously taken human osteology. Students were able to reconstruct the external bones of the deer skulls. They had difficulty when they encountered bones that are not present in modern humans, but were able to refer to a labeled skull for assistance. As the internal skull morphology was not required for this activity, a higher-level course should require internal skeletal structures also be repaired.

The students expressed hesitance when they were assigned a deer skull, because they learned specifically about human materials all semester. Spending time explaining homology and giving the students a labeled deer-skull key (6) assisted in emphasizing why this experience was relevant and helped the students understand why they were working on deer skulls.

Students likewise struggled when encountering small bone fragments and lacked patience when articulating bones. The students were adamant about holding the bones together until they dried instead of attaching them and setting them down to dry or creating a brace. By insisting on manual bracing while the adhesive dried, they lost a lot of laboratory time and increased their out-of-class time to complete the project.

During the skeletal analysis, students were challenged not just while reconstructing small pieces of bone but also while differentiating between weathering and other trauma. This can be corrected with more exposure to hands-on skeletal material exhibiting a variety of weathering and/or trauma. All three groups were able to reconstruct the external morphology including small fragments. In the groups, students were able to properly identify fractured bones, number of blows, and differentiate between the intentional traumatic tool marks and the unintentional flensing marks.

After articulating the damaged bone, the students wrote a lab report and submitted a scientific research poster documenting their analysis. Incorporating in-class undergraduate research projects helps the students realize they are engaged in real science and that these projects have the potential to be presented at small regional scientific meetings. Students are also able to appreciate the relevance while gaining actual experience in the field and related skills.

Student survey results stated that 83% of students enjoyed the project and 16.6% neither enjoyed nor disliked the project. Student comments about the reconstruction project were positive, stating they enjoyed the project and felt the hands-on approach helped them understand skeletal trauma. The entire class (100%) believed this project increased their knowledge in forensic anthropology and made them feel more competent in the subject (Table 1).

TABLE 1 Survey results based on anonymous student feedback (n=6).

Survey questions	**N=6**
I enjoyed this project	33.3% - Strongly agree 50% - Agree 16.6% - Neither agree or disagree
I feel I gained more from this project compared to other lab activities.	16.6% - Strongly agree 66.6% - Agree 16.6% - Neither agree or disagree
I learned from this project.	66.6% - Strongly agree 33.3% - Agree
This project increased my forensic anthropology knowledge.	33.3% Strongly agree 66.6% - Agree
This project made me feel more competent in the field of forensic anthropology.	16.6% - Strongly agree 83.3% - Agree
I enjoyed the hands-on aspect of this project.	66.6% - Strongly agree 16.6% - Agree 16.6 - Neither agree or disagree

Students were also asked about the ethical reasons for not using authentic human remains. Results suggested that 100% of students understood why real remains were not used. Furthermore, 16.6% of students wanted to reconstruct while 50% did not agree or disagree, and 33.3% did not want to practice on a human skull. Finally, 50% of students would not want to practice on real skeletal remains while the other 50% neither agreed nor disagreed.

Pre and post exams were used to evaluate if the laboratory activity increased test scores. These exam results were not obtained in the ideal situation as the post-exam was part of the students' final exam and may have altered the students' normal performance. On average there was an increase of 1.2% from the pre-exam to the post-exam. Half of the class had an increase in score for the post-exam while the other half saw a decrease. The highest increase was 8% and the lowest was -10%.

Discussion/Conclusion

This course had a very small sample size, but based on student feedback and overall classroom energy it was a good laboratory activity. The activity is relatively simple to set up if an instructor has access to dermestid beetles, and the activity can be adjusted or can incorporate different types of trauma on different bones. When I offer forensic anthropology again in spring 2022, I plan to repeat this lab activity.

One potential way to improve the student experience would be incorporating long bones into this project, and they are easier to flense and skeletonize when compared to skulls. When using long bones it is easier to observe trauma because these bones are less likely to shatter compared to bones of the skull. Students can observe and reconstruct various types of long bone breaks as well as compare and contrast tools to create trauma. To make this a more advanced activity, this lab can be enhanced to analyze velocity, tools, shatter patterns, etc. Importantly, students take an active role in determining what variables to manipulate and to what magnitude. For example, students may diversify weapon selection or modify a given tool (e.g., hammer type, size, and amount of force). They can also examine various forms of cut marks and saw markings (e.g., manual versus automated, striation pattern, blade thickness). Other than in-class activities, undergraduate research opportunities are also available, worthwhile, and represent practical learning opportunities unto themselves.

Based on student feedback, the reconstruction activity allowed students to feel as if they enhanced their knowledge, and all students felt they were more competent in the field of forensic anthropology. Even though the majority of students stated that they enjoyed the project and felt that they learned, pre and post exam scores do not reflect this. This may be explained by a difference in test format versus the lab experience. The test consisted of photographs of human skulls that underwent different trauma and the students had to analyze the skull, similar to this lab experience. Perhaps the difference in species or lack of tactile manipulation diminished test improvement. With respect to the post-test, there were two confounding variables as well: the final exam was computer-based whereas the pre-test had been paper, and the final exam was proctored.

Half of the class had a score increase of 7%. These scores were consistent with the passing grade received on the lab assignment and level of effort they were observed putting into the reconstruction assignment. Two students had a slight decrease in exam scores (-2%). These students also invested significant effort, but this did not carry over to their exam scores. One outlier's score saw a decrease of 10%. This student was not observed exercsing considerable effort and this was reflected in the partner's survey. Again, these results should not be viewed as significant as the pre and post-test were under different circumstances. Generally, it appeared that students who invested the greatest effort in lab enjoyed greater improvements on the examination.

When evaluating the effectiveness of this lab activity in the future, better attention will be paid to controlling extraneous variables. The format for pre and post testing will be identical (e.g., paper or computer-based), the testing will be administered by the same faculty, and the post test will be weighted no differently than the pre-test. Other intervening variables are more challenging to manage. For example, the testing on human remains versus animal materials being utilized in lab may be a valid approach because, occupationally, students will be responsible for examining human remains. Similarly, although the students are manipulating three-dimensional specimens in lab and were tested using photographs, there may be instances when they have access to only specimen photographs. These represent challenges students will face in the field.

In conclusion, vertebrate laboratory activities using dermestid beetles are inexpensive and easy to organize. This project offers hands-on reconstruction of remains which is not possible with most laboratory activities. It enhances the lab activities and allows students to actively participate.

Students found the activity very gratifying, and this showed as the students invested considerable out-of-class effort. Survey results also indicated that students felt they learned a lot and were more competent in the field. This could not be confirmed with pre and post exam results, but student scores on the project were favorable.

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